EFFECTS OF A BEACH/HABITAT BUILDING FLOW ON CAMPSITES IN THE GRAND CANYON

DRAFT REPORT

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by

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ABSTRACT

Large riverside sand deposits located above daily river fluctuations are used as campsites in Grand Canyon National Park. The combination of a loss in high elevation sand deposits with an increase in campsite use since the operation of upstream Glen Canyon Dam has prompted a great deal of concern over present and future campsite availability. Because of this concern over how Glen Canyon Dam has affected campsites as well as many other resources in the Grand Canyon, an effort was made to reintroduce flooding, an integral component of the pre-dam river. In March 1996, an experimental "flood" consisting of a week-long discharge well above normal dam operations was released from the dam as part of a research experiment designed, in part, to resore high elevation sand deposits in the Grand Canyon. Preliminary studies had indicated that this flood would help move sediment to higher elevations thus expanding campsite availability. The present study evaluates effects of the experimental flood on campsite number, size, and longevity.

Campsites were evaluated by quickly assessing changes to nearly all campsites, by mapping pre- and post-flood campsite area for a quarter of the sites, and by documenting and when feasible measuring new flood-created sites. We performed quick, float-by assessments for 92% (200/218) of all established campsites, noting whether campsite area substantially changed after the flood. Half (49%) increased in size, 39% remained the same, and 12% became smaller.

We measured campsite area at 53 established sites directly before, after, and 6 months after the test flow. All mapped sites increased in area by a mean of $144m^2$ from an original mean area of $700m^2$, increasing on average by 57%. Of those that increased in size, campsite area increased by a mean of $344m^2$, increasing on average by 204%. Campsites in "critical reaches," narrow reaches of the river that have a disproportionaltely limited number of campsites, increased in area on average by 75%, while those in non-critical reaches increased by 31%. There was no difference between changes in campsite area above versus below the Little Colorado River (LCR), a major tributary that flows into the mainstem. The test flow created 82 and destroyed 3 campsites. These new sites accommodated on average 20 people per site, and of those measured had a mean area of $477m^2$, about half the mean area of established sites after the flood. More than twice as many campsites per mile were created above the LCR versus below the LCR and in non-critical reaches versus critical reaches.

Note: Because of the short (5-day) time period between the 6-month post-flood trip and the deadline for this draft report, no data on 6-month changes to campsites are included here. Because of the incomplete data set at the time of this report, statistical analysis, additional figures, and maps of established and new campsites are not included in this draft report but will be included in the final report.

INTRODUCTION

Sediment deposits along the Colorado River in the Grand Canyon serve as campsites for river runners, as habitat for vegetation and wildlife, and represent sand storage in the system. While river use has increased in the past 30 years to approximately 22,000 people per year, the number and size of campsites has markedly decreased (Kearsley et al. 1994). As a result, campsites in narrow stretches of the river are extremely limited, causing severe competition and excessive use.

These decreases to campsite area are a result of changes to the river caused by Glen Canyon Dam and its operations (Beus et al. 1985; Schmidt and Graf 1990; consensus of long-term river guides). Glen Canyon Dam, completed in 1963, greatly reduced the river's sediment load and its flooding capability. The dam traps essentially all upstream sediment so that all downstream sediment is contributed by flash flooding events and downstream tributaries, primarily the Paria River and the LCR. These present day sources, however, contribute only a fraction of the pre-dam sediment load. Until the March 1996 test flood, dam operating criteria have not incorporated flooding into their discharge regime. Mean annnual flooding during the 40 years preceding Glen Canyon Dam was 77,000 cubic feet per second (cfs) (Kieffer et al. 1989). Under current interim dam operations maximum discharge is restricted to 20,000 cfs; however, unplanned flooding events have occurred when Lake Powell backing Glen Canyon Dam has been full and inflow has been high.

Concern over Glen Canyon Dam's effects on sediment deposits as well as many other resources in Grand Canyon prompted political action during the past decade. The Bureau of Reclamation's Glen Canyon Environmental Studies (GCES) program was initiated in 1982 (National Research Council 1987), which lead to an environmental impact statement (EIS), released in 1995 (Bureau of Reclamation 1995), to resolve management of these resources. The EIS initiated a plethora of resource-related studies in the Grand Canyon, many of which focused on sediment. During this time, US Congress passed the Grand Canyon Protection Act which required that scientific information be used to ensure that dam operations would not damage natural resources in Grand Canyon by mandating moderated interim flows.

Aerial photograph analysis and campsite inventories show a 30-year trend of diminishing campsites punctuated by infrequent flood-induced increases. Between 1965, two years after Glen Canyon Dam was completed, and 1973, nearly 1/3 of all campsites ceased to exist or decreased substantially in size due to erosion (Kearsley et al. 1994). The first campsite inventory provided a baseline campsite number, documenting 333 campsites in 1973 (Weeden et al. 1975). The second inventory, preceded by flood level flows of 96,000 cfs, documented 438 campsites in 1983, a 34% increase in number. The increased number of campsites since 1973 were primarily attributed to the previous year's flood releases (Brian and Thomas 1984). Aerial photograph analysis showed that these flood-induced increases were short-lived. One year after the inventory most of these new and larger campsites had substantially eroded (Kearsley et al. 1994). The most recent inventory documented 226 campsites in 1991, a 32% reduction in campsite number since 1973, and a 48% reduction since 1983 (Kearsley and Warren, 1993).

Flood-induced changes, however, vary widely across individual beaches and in response to sediment storage in the river bed (Hazel et al. 1993; Schmidt and Leschin 1995). While most campsites increased in size in 1983, many remained relatively the same size, and a few decreased. Discharges in 1984-1986 were also quite high with peak flows between 48,000 and 58,000 cfs; however, most sites eroded during these years. While high erosion rates after depositional flooding account for much of the erosion that occurred (Beus et al. 1985; Schmidt and Graf, 1990; Hazel et al. 1993), a principal mechanism is likely due to the small amount of sediment stored on the river bed in 1984-1986, causing the high flows to be more erosive (Kearsley et al. 1994). Between 1965 and 1983, a great deal of sediment from tributaries had accumulated on the river bed, so was available for deposition in 1983 (Randle et al. 1993). Very little sediment remained by 1984, so the high flows during the next few years augmented the erosion process (Kearsley et al. 1994).

Continued monitoring of campsites found more moderate decreases in campsite size as well as flood-induced increases. Ninety-three campsites were measured annually from 1991 to 1994 by on-site mapping using aerial photographs. The measured campsites lost on average 9% of their total area during this time. In 1993, a natural flood event from the Little Colorado River raised the mainstem's discharge below the Little Colorado River to 33,000 cfs (U.S. Geological Survey 1994). Half of all measured campsites increased in size, primarily below the Little Colorado River. A year later most of this increased area eroded; however, some campsites remained larger in 1993 than they were in their initial 1991 measurements (Kearsley 1995).

As a result of these flood-related findings, the EIS incorporated a beach/habitat-building flow within its preferred alternative. This high flow would consist of a 45,000 cfs discharge for 1-2 weeks approximately every five years in part to rebuild high elevation sandbars. In order to determine whether its impacts would adhere to researchers' predictions, the EIS proposed conducting a test beach/habitat-building flow before incorporating it into the final alternative. This test flow of 45,000 cfs was conducted from March 27-April 3, 1996. The present study evaluates its effects on campsite number and size, and the 6-month longevity of these changes.

STUDY AREA

Campsites were measured along the Colorado River in the Grand Canyon between Lees Ferry and Diamond Creek (river mile 0-226) (Figure 1). Lees Ferry, located 15 miles downstream from Glen Canyon Dam, is the launch point for Grand Canyon river trips, and Diamond Creek is the first road access from which boats can depart. The study area is subdivided into reaches based on the number of campsites available in relation to recreational demand. "Critical reaches" of the river have a limited number of available campsites, and competition for sites is greater than for sites on other stretches of the river (Kearsley and Warren, 1993). Critical reaches are located 11-40.8, 75.6-116, and 131-164 miles downstream from Lees Ferry. Non-critical reaches are river mile 0-11, 40.8-75.6, 116-131, and 164-226. Critical and non-critical reaches, based on recreational considerations, correspond closely to Schmidt and Graf's (1990) narrow and wide reach designations, based on river geomorphology.

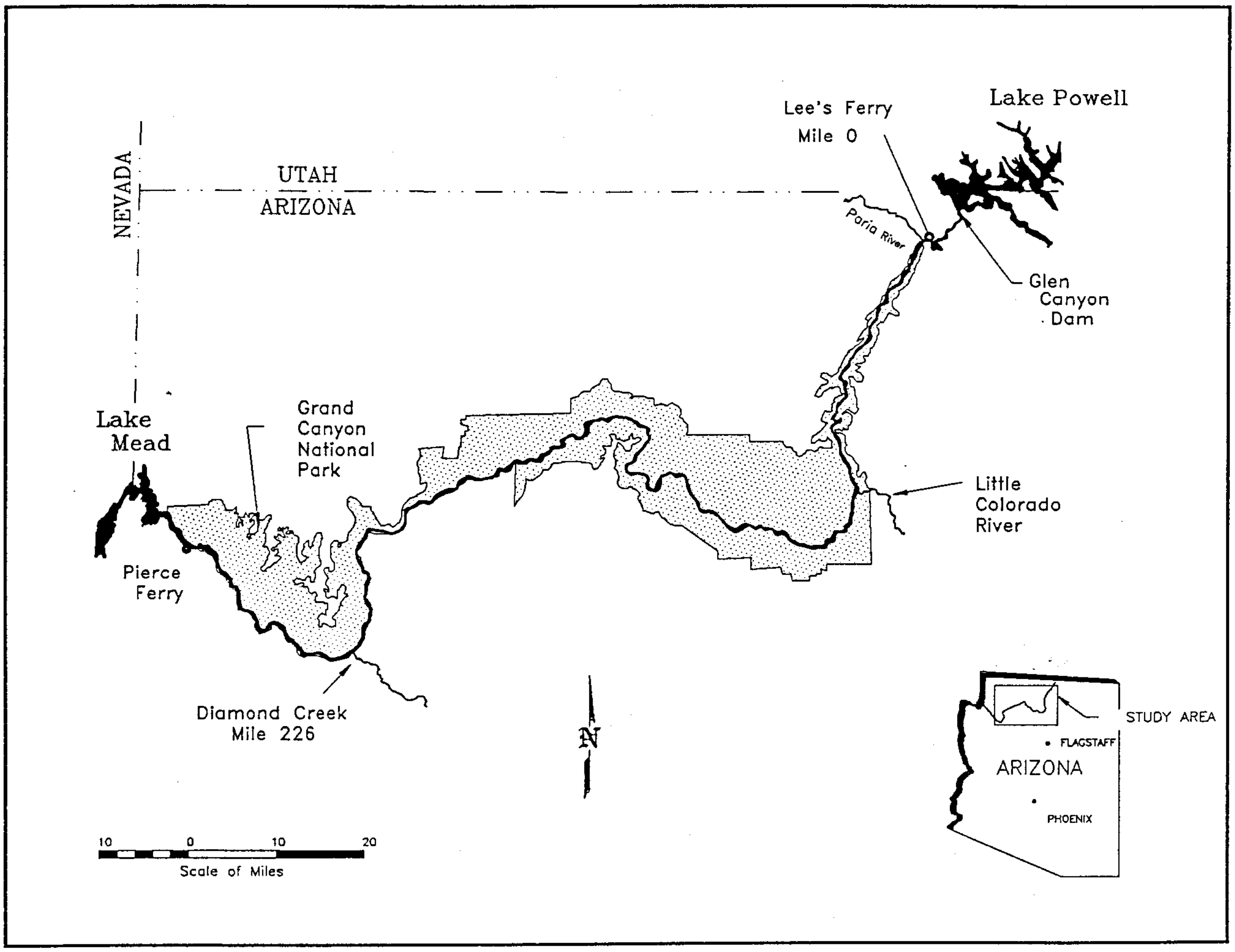

Figure 1. Map of study area

METHODS

Our most comprehensive evaluation involved quickly assessing flood-induced changes to nearly all campsites in the Grand Canyon. Two weeks after the experimental flood, we performed quick, float-by assessments for 200 (92%) of the 218 sandbar campsites that existed before the flood. Documentation and location of the 218 established camps was based on the 1991 campsite inventory (Kearsley and Warren 1993) with some adjustments we made to the list during our pre-flood trip to exclude campsites exclusively on bedrock ledges and to account for site degradation subsequent to the 1991 inventory. Post-flood assessments of these sites consisted of evaluating campsites on-river and deciding, based on our knowledge of the campsites' pre-flood condition, whether the sites appeared to have gained or lost at least ten percent of their pre-flood campsite area, or whether they appeared the same.

Our more in-depth evaluation involved mapping campsite area of 53 of the 218 campsites two weeks before, two weeks after, and six months after the flood. We also photographed nearly all the sites during these time periods. These sites were randomly selected within each reach from the original 93 campsites that were measured annually from 1991-1994. We mapped campable area above 20,000 cfs for each site. Areas below 20,000 cfs were not mapped because these areas are often not available under the current dam operations. Mapping consisted of the following steps: 1) Laser xerox copies of the 1:4800 spring 1995 aerial photographs enlarged 400% were used as base maps for the pre-flood measurements, and copies of the spring 1996 post-flood photographs were used for both post-flood measurements; 2) Because of high dam discharges at or close to 20,000 cfs throughout the study period, current water levels and cutbanks were sufficient to determine where the 20,000 cfs water line was at each campsite. We also took pre-flood photographs of the 20,000 cfs line to ensure accurate relocation for the subsequent measurements; 3) While visiting each site, we outlined the perimeter of campable area above 20,000 cfs onto a mylar overlay of the basemap. Campable area is a smooth substrate (almost always sand) with less than an eight degree slope that has little to no vegetation; basically, area that you could easily sleep or put a kitchen on. Bushes, trees, and boulders seen on the basemap were used as references for campsite area delineations onto the maps. Where campable area perimeters were not near visual references, we measured distances from the perimeter to visual landmarks in order to later check and sometimes adjust our line placement. While the areas of the larger polygons were later calculated using Geographic Information System (GIS), the length and width of smaller outlying sleep spots, usually less than 10 meters squared (m^2), were measured on-site; and 4) Some of the measured sites are within GCES GIS reaches, reaches which have high accuracy geodetic survey control points established. We entered campsite area for these sites into the GCES GIS, using rocks and bushes visible on both the campsite basemap and the GIS reach orthophoto as tic marks to transform the coverage into Arizona stateplane coordinates. For the sites outside of the GIS reaches, we measured distances between rocks or bushes visible on the basemap while visiting each site. After digitizing the maps into GIS, we used the digitized distance to calculate a conversion factor to convert campsite area from digitizer inches to square meters.

We also documented all, and measured many, of the new campsites created by the flood during our two-week and six-month post-flood trips. To attain "new campsite" status, the site must have access between mooring and camping areas, have sufficient space to accommodate a kitchen and 10 or more people, and not be overgrown with vegetation (Kearsley and Warren 1993). We stopped at prospective new campsites, estimated the site's capacity for people and a kitchen while walking on the site, and, when time allowed, mapped campsite area for many of the sites and photographed them. Since we did not have prior knowledge of the new campsites' locations, we did not have a basemap from which to map campsite area, so drew maps on a blank sheet of paper and took length by width measurements of campsite areas. After the post-flood aerial photographs became available, we transferred our maps onto the enlarged laser xeroxes of the photographs when our drawn maps correlated well with the xeroxes of the actual sites. For sites that did not transfer well, we retained and used only the lengh by width measurements of the site. These different assessment methods resulted in documentation and a capacity estimate of all new sites, maps of many of the sites, and length by width measurements of a few of the sites two weeks and six months after the flood.

RESULTS

Overall Assessment

Our quick assessments of 92% of all campsites showed a pronounced system-wide increase in campsite area. Half (98/200) of the sites were at least ten percent larger, 39% (77/200) were the same, and 12% (24/200) were smaller than they had been prior to the flood (Appendix A). It is important to note that sand deposition at a site did not always correlate with increased size of the site. Many sites experienced sand deposition on top of campable area already above 20,000 cfs, resulting in higher elevation sand with no increase in campable area. Some sites actually became narrower or gained a mound of sand upon previously campable area, so that sand deposition increased the volume of the sand at the site but decreased the area upon which people could camp. Evaluations of the amount of sand at each site irrespective of how it affected campsite area showed an even sharper increase. There was a substantial increase in sand at 72% (144/200) of the sites, little to no change at 23% of the sites, and a decrease at 5% of the sites. It must be emphasized that these are quick, rough assessments; however, what they lack in technological measurements, they make up for in documentation of the experimental flood's effect on nearly every sandbar suitable for camping in the Grand Canyon.

Measured Established Campsites

The 53 established campsites that were measured before and after the test flood increased in area by a mean of $144m^2$ from an original mean area of $700m^2$, increasing on average by 57% (Appendix B). Of those that increased in size, campsite area increased by a mean of $344m^2$, increasing on average by 204%. Of those that decreased in size, campsite area decreased by a mean of $355m^2$, decreasing on average by 59%. Because critical reaches are located in Grand Canyon's gorges where the river is much narrower, campsites in these reaches are much smaller than in non-critical reaches. They responded differently than sites in non-critical reaches by increasing in less actual area but by a larger percentage of their original area. All measured sites in critical reaches increased by a mean of $97m^2$, while those in non-critical reaches increased by a mean of $210m^2$. However, measured campsites in critical reaches increased by an average of 75% of their original area, while those in non-critical reaches increased by 31%. Campsites above versus below the LCR behaved similarily, with all measured sites above the LCR increasing in area by 48% of their original area, and sites below the LCR increasing by 60%.

New Campsites

Eighty-two new campsites were created (Appendix C) and 3 sites were destroyed by the test flood. These sites are new in the sense that they could not accommodate 10 or more people plus a kitchen directly prior to the flood. However, 33 of these sites were large enough in previous years to be included in the 1973, 1983, and/or the 1991 campsite inventories but had since degraded so that they were not suitable as campsites by 1996. These sites accommodated on average 20 people per site. Many of the new sites consisted of exposed bars jutting out into the river, offering no protection from sun or wind. These types of sites generally are not popular but are useable as campsites. A few sites were created by deposition of sand on top of a high elevation bar that was overgrown with vegetation. The new sand covered up most of the vegetation, creating ample camping space. The 3 campsites destroyed by the flood, river miles 61.7R ("below the LCR"), 164.8L ("below Tuckup") and 196.5L ("below Frogy Fault"), experienced sand scouring which obliterated most of their campsite area.

These new campsites were not uniformly distributed by river mile or by reach type. Forty percent of the new sites were created in a 25-mile section between river miles 40-65, with an average of 1.3 new sites/mile (Figure 2). More campsites per mile were created above the LCR versus below the LCR so that on average, one new site occurred every 1.6 miles above the LCR and every 3.7 miles below the LCR. More than twice as many campsites were created in non-critical reaches (59/82) than in critical reaches (23/82). With respect to the length of each reach type, a new campsite was created on average every 2 miles in non-critical reaches and every 4.5 miles in critical reaches.

We measured 33 new campsites: 20 were mapped and 13 were roughly measured by recording length by width of campable area. The mean area of the 33 sites was 477 m^2, about half the mean area of the 53 established sites measured after the flood. However, not all of the measured campable area at these new sites was created by the flood. Some sites, especially sites

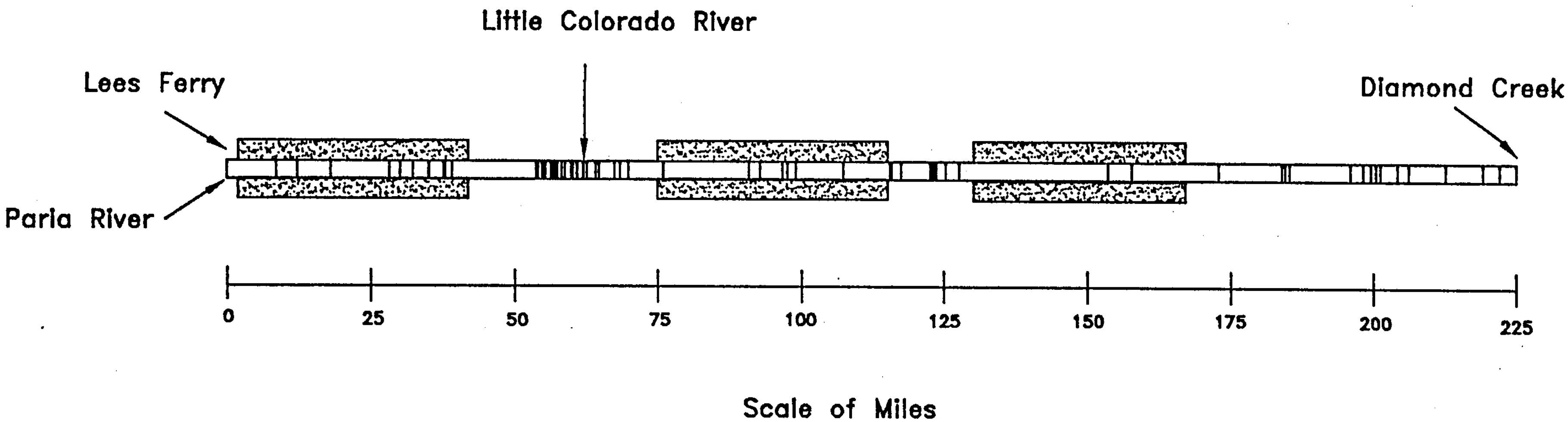

Figure 2. Schematic showing distribution of new campsites. Horizontal bar depicts Colorado River. Lines crossing bar show locations of new campsites. Stippled areas represent critical reaches.

that had been included in previous inventories, had numerous sleeping areas before the flood but no main area to serve as a kitchen, so could not be used as campsites. The flood created a front bar large enough to be used for a kitchen and sleeping areas, which then enabled the entire area, including campable areas above 45,000 cfs to be used.

DISCUSSION

The test flow has irrefutably increased the number, size, and, consequently, capacity of campsites in the Grand Canyon. Under the right conditions, an occasional high flow improves more than four times as many campsites than it degrades and creates many new campsites; thus, the incorporation of flood flows into Glen Canyon Dam's future operations would benefit campsites. However, 45,000 cfs may not be the ideal high discharge for periodic augmentation of campsites. A number of sites were scoured and some were destroyed by the flood. Eddies associated with these sites would likely remain intact at lower discharge levels, allowing for sand augmentation rather than scouring at many of these sites. In comparison, none of the 93 campsites measured in 1993 were destroyed by that year's natural LCR flood of 33,000 cfs. Also, sand bars created at 45,000 cfs are approximately 2-3 meters above last year's average maximum flow of 15,200 cfs (mean flow from Oct 1994-Oct 1995; Bureau of Reclamation, Glen Canyon Dam power plant releases). This vertical displacement between moored boats and campsite area must be negotioated for each trip from the boats which, while annoying for empty-handed trips, can be fairly difficult when lugging kitchen and personal gear. Based solely on recreational considerations, a lower flood discharge would likely cause more positive and fewer negative changes to campsites.

One area of concern over whether the test flood would aggrade or further erode sandbars was Marble Canyon, which begins at Lees Ferry and ends at the LCR. This concern was raised because the Paria River is the regions's only sizeable sediment source, so there was uncertainty as to whether the river bed had accumulated enough sediment to aggrade sandbars. However, the high density of new campsites above the LCR, with more than twice the number of new sites per mile than below the LCR documents that not only did the flood not erode sandbars in Marble Canyon, it aggraded sites more than in any other section of the Grand Canyon.

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APPENDIX A

List of flood-induced changes to all evaluated campsites (n=200) in Grand Canyon. Campsites were evaluated April 1996, two weeks after the flood and were compared to their condition two weeks prior to the flood.

These data are entered on a Lotus 1-2-3 spreadsheet file. Data columns are as follows:

MILE	campsite location according to river mile
SIDE	side of the river while facing downstream
NAME	campsite name
REACH	reach type: **C** = critical reaches (see text for reach definitions and locations) **NC** = non-critical reaches
AREA	post-flood changes to campsite area: **I** = area substantially increased **S** = area remained the same **D** = area substantially decreased
SAND	post-flood changes to the amount of sand at campsite irrespective of changes to campsite area: **I** = amount of sand substantially increased **S** = amount of sand remained the same **D** = amount of sand substantially decreased
NOTES	Pertinent notes about campsite changes. Only notes containing information beyond that found in AREA and SAND columns are included.

MILE	SIDE	REACH	NAME	AREA	SAND	NOTES
8.0	R	NC	BADGER	I	I	
8.0	L	NC	JACKASS	I	I	
11.0	R	C	SOAP CREEK	S	S	
16.4	L	C	HOT NA NA	I	I	
17.0	R	C	HOUSE ROCK	I	I	
19.0	R	C		D	I	LESS AREA, MORE SAND HIGHER UP
19.1	L	C		D	S	US-NEW, STEEP SAND MOUND. DS-SCOURED
19.9	L	C		S	S	MORE AREA BUT DOWNSTREAM SECTION HARD TO REACH
20.4	R	C	UPR NORTH CYN	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
20.5	R	C	LWR NORTH CYN	I	I	
21.5	L	C		I	I	
21.9	R	C		I	I	
23.0	L	C	INDIAN DICK	I	I	
23.7	L	C	LONE CEDAR	S	S	
24.5	L	C	241/2 MILE	S	S	
26.3	L	C	ABOVE TIGER W	I	I	
29.3	L	C	SHINUMO WASH	I	I	
30.4	R	C	FENCE FAULT	I	I	
31.6	R	C	SOUTH CANYON	I	I	JUST OVER 10% LARGER
33.6	L	C	BELOW REDWALL	S	S	
34.0	L	C	LITTLE REDWALL	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
34.8	L	C	NAUTILOID	I	I	
37.7	L	C	TATAHATSO	I	I	
38.3	L	C	MARTHA'S	S	S	
39.0	R	C	REDBUD ALCOVE	D	S	LESS AREA. POORER AESTHETICS
40.9	R	NC	UPR BUCKFARM	S	S	
41.0	R	NC	LWR BUCKFARM	I	I	
43.2	L	NC	ANASAZI BRIDGE	I	I	SAND COVERED WILLOWS, SO MORE AREA
[illegible]	L	NC	LWR ANASAZI	S	S	
[illegible]	L	NC	EMINENCE	I	I	
44.6	L	NC		S	S	
44.8	L	NC	WILLIE TAYLOR	I	I	
46.9	L	NC	DUCK N QUACK	S	S	
47.2	R	NC	UPR SADDLE	S	S	
47.3	R	NC	LWR SADDLE	I	I	
50.0	R	NC	DINOSAUR	S	S	
51.2	L	NC		I	I	
51.8	R	NC	LITTLE NANKOWEAP	S	S	
52.6	R	NC	UPR NANKOWEAP	I	I	
53.0	R	NC	NANKOWEAP	S	S	
56.2	R	NC	LWR NANKOWEAP	I	I	
56.7	R	NC		I	I	
57.5	R	NC	MALGOSA	I	I	
57.5	L	NC		I	I	
58.2	R	NC	AWATUBI	S	S	
58.6	L	NC		I	I	
59.0	R	NC		I	I	
59.8	R	NC	60-MILE	S	S	
60.8	R	NC		S	S	
61.0	L	NC		S	S	
61.2	R	NC	ABOVE LCR	I	I	
61.7	R	NC	BELOW LCR	D	D	CAMP DESTROYED BY FLOOD. DOWNSTREAM MAIN AREA GONE
62.6	R	NC	CRASH CYN	S	S	
64.7	R	NC	CARBON	I	I	
65.5	R	NC	LAVA CYN	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
65.7	L	NC	PALISADE CK	S	S	
66.3	L	NC		I	I	
66.8	L	NC	ESPEJO	I	I	
68.4	R	NC	TANNER	I	I	
[illegible]	R	NC	LWR BASALT	I	I	
71.0	L	NC	CARDENAS	I	I	

MILE	SIDE	REACH	NAME	AREA	SAND	NOTES
71.9	R	NC	UPR UNKAR	S	S	
72.3	L	NC	UNKAR	I	I	
73.6	R	NC	BELOW GRANARY	I	I	
74.1	R	NC	UPR RATTLESNAKE	I	I	
74.3	R	NC	LWR RATTLESNAKE	I	I	
75.6	L	C	NEVILLS	I	I	
75.8	R	C	PAPAGO	S	S	
76.6	L	C	HANCE	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
78.9	L	C	BELOW SOCK	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
81.3	L	C	GRAPEVINE	I	I	
84.0	R	C	CLEAR CK	I	I	
84.4	L	C	ABOVE ZOROASTER	I	I	
87.1	L	C	UPR CREMATION	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
87.2	L	C	LWR CREMATION	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
89.3	R	C	BELOW PIPE CK	I	I	
91.1	R	C	91-MILE CK	I	I	
91.6	R	C	TRINITY CK	I	I	
92.3	L	C	ABOVE SALT CK	S	S	
93.4	L	C	GRANITE	D	S	NEW SAND HIGHER UP, BUT MAIN AREA NARROWER
94.3	R	C		I	I	
94.9	L	C	HERMIT	S	S	
96.0	R	C	UPR SCHIST	I	I	
96.1	L	C	SCHIST	I	I	
98.0	R	C	UPR CRYSTAL	D	D	MAIN AREA SCOURED, UPSTREAM AREAS INACCESSIBLE
102.8	R	C	NEW SHADY GROVE	I	I	
103.8	R	C	EMERALD	I	I	
107.8	L	C	ROSS WHEELER	D	D	SCOURED. DECREASED AREA
108.0	R	C	PARKINS' INSCR	I	I	
[illegible].2	R	C	LWR BASS	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
[illegible].4	R	C	110-MILE	D	D	MUCH SCOURING. DECREASED AREA
114.3	R	C	UPR GARNET	S	I	
118.1	R	NC		I	I	
118.5	L	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
119.0	R	NC	BIG DUNE	I	I	
119.2	R	NC		I	I	
119.5	L	NC	SHADY GROVE	I	I	
119.8	L	NC	120-MILE	S	I	
120.0	R	NC	UPR BLACKTAIL	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
120.1	R	NC	LWR BLACKTAIL	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
120.2	L	NC		D	D	MAIN AND DOWNSTREAM AREAS SCOURED. MUCH SMALLER
120.9	L	NC		S	S	
122.2	R	NC	122-MILE	D	I	
122.7	L	NC	UPR FORSTER	I	I	
125.4	L	NC	BELOW FOSSIL	I	I	
126.5	R	NC	RANDY'S ROCK	D	D	MOST OF LOWER AREA GONE
131.1	R	C	BELOW BEDROCK	D	D	MUCH OF MAIN AREA GONE
131.8	R	C	GALLOWAY	S	S	
132.0	R	C	STONE CK	I	I	
133.0	L	C	TALKING HEADS	I	I	
133.5	R	C	RACETRACK	I	I	
133.8	R	C	TAPEATS	S	S	
133.9	R	C	BELOW TAPEATS	I	I	
134.2	L	C		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
134.6	L	C	OWL EYES	I	I	
136.0	L	C	JUNEBUG	S	S	
136.2	L	C	ACROSS DEER CK	S	S	
136.3	L	C	OC'S	I	I	
136.8	L	C	PONCHO'S KITCHEN	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
[illegible]6.9	L	C	FOOTBALL FIELD	I	I	
[illegible].0	L	C	BACKEDDY	D	S	HIGH BERM BETWEEN MAIN AREA AND RIVER, DRIFTWOOD
137.9	L	C	DORIS	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE

MILE	SIDE	REACH	NAME	AREA	SAND	NOTES
138.2	L	C		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
138.4	L	C		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
139.0	R	C	FISHTAIL	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
139.8	L	C	KEYHOLE	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
143.3	L	C	ABOVE KANAB	I	I	
143.5	R	C	MOUTH OF KANAB	I	I	
144.2	R	C	BELOW KANAB	S	S	
145.1	L	C	ABOVE OLO	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
145.6	L	C	OLO	I	I	
147.9	R	C	OPP MATKAT	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
148.4	L	C	MATKAT HOTEL	I	I	
148.5	L	C	BELOW MATKAT	D	S	GAIN AND LOSS OF CAMP AREA
150.3	L	C	UPSET HOTEL	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
155.7	R	C	LAST CHANCE	I	I	
157.7	R	C	FIRST CHANCE	I	I	
158.5	R	C	SECOND CHANCE	I	I	
160.0	L	C	160-MILE	D	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
160.7	R	C		I	I	
164.5	R	NC	TUCKUP	I	I	
164.8	L	NC	BELOW TUCKUP	D	D	CAMP DESTROYED BY FLOOD
166.5	L	NC	UPR NATIONAL	D	D	LESS AREA ALONG RIVER
166.6	L	NC	LWR NATIONAL	S	I	
167.0	L	NC	BELOW NATIONAL	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
167.2	L	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
168.0	R	NC	FERN GLEN	I	I	
171.0	R	NC	STAIRWAY CYN	S	S	
171.6	L	NC	MOHAWK	I	I	
172.1	L	NC	172-MILE	I	I	
173.0	R	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
174.3	R	NC	UPR COVE	I	I	
174.4	R	NC	LWR COVE	I	I	
176.0	L	NC	BELOW RED SLIDE	I	I	
177.1	L	NC	HONGA SPRING	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
177.7	L	NC	ABOVE ANVIL	I	I	
178.0	R	NC	VULCAN'S ANVIL	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
179.0	L	NC	ABOVE LAVA	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
179.2	L	NC	JUST ABOVE LAVA	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
179.7	R	NC	BELOW LWR LAVA	S	S	
182.5	R	NC	UPR CHEVRON	I	I	
182.6	R	NC	LWR CHEVRON	I	I	
182.8	R	NC	BELOW CHEVRON	I	I	
182.8	L	NC		I	I	
183.0	L	NC	BELOW OLD HEDIPAD	S	S	
184.5	L	NC		I	I	
185.5	R	NC		S	S	
186.0	L	NC		D	D	MOST OF CAMP AREA ALONG RIVER GONE
188.0	R	NC	WHITMORE WASH	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
188.2	R	NC	LWR WHITMORE	I	I	
189.5	L	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
189.7	L	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
190.3	L	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
191.0	R	NC	UPPER FAT CITY	S	I	
191.8	L	NC	FAT CITY	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
192.2	R	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
192.8	L	NC		S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
194.1	L	NC	HUALAPAI ACRES	I	I	
196.4	L	NC	FROGY FAULT	S	I	NEW SAND HIGHER UP, BUT NO AREA CHANGE
196.5	L	NC	BELOW FROGY	D	D	CAMP DESTROYED. HEAVY GULLY EROSION
198.5	R	NC	PARASHANT	I	I	
202.0	R	NC	202-MILE	D	S	RIVER SIDE OF MAIN AREA GONE. ALSO, NEW SAND HIGHER UP
202.5	R	NC		I	I	

MILE	SIDE	REACH	NAME	AREA	SAND	NOTES
204.5	R	NC	BELOW SPRING CYN	I	I	
206.6	R	NC	INDIAN CYN	I	I	
208.8	L	NC	GRANITE PARK	S	S	
209.5	R	NC		I	I	
210.7	R	NC	BIG CEDAR	I	I	
211.2	L	NC		I	I	
212.9	L	NC	PUMPKIN SPRINGS	I	I	
215.6	R	NC	OPP THREE SPRING	I	I	
216.4	R	NC		D	S	NARROWER, NEW SAND HIGHER UP
219.8	R	NC	UPPER 220-MILE	S	I	
219.9	R	NC	MIDDLE 220-MILE	D	I	MORE SAND BUT LESS AREA
220.0	R	NC	LOWER 220-MILE	D	S	NARROWER. ALSO, NEW SAND HIGHER UP
221.2	R	NC	221-MILE	I	I	
222.0	L	NC	222-MILE	I	S	SAND LOSS AND GAIN. A TRADE-OFF
223.0	R	NC	223-MILE	S	S	
223.4	L	NC	224-MILE	I	I	
224.5	L	NC		I	I	

APPENDIX B

List of established campistes that were mapped (n = 53). Mapping occurred in March 1996, two weeks prior to the flood and in April 1996, two weeks after the flood.

These data are entered on a Lotus 1-2-3 spreadsheet file. Data columns are as follows:

MILE	campsite location according to river mile	
NAME	campsite name	
REACH	reach type:	**C** = critical reaches (see text for reach definitions and locations)
		NC = non-critical reaches
PREAREA	campsite area in meters squared 2 weeks prior to the flood	
POSTAREA	campsite area in meters squared 2 weeks after the flood	
AREACHG	how campsite area changed:	
		I = area increased by >10%
		S = area remained the same
		D = area decreased by >10%
%	percent change in campsite area (POSTAREA/PREAREA)	

MILE	NAME	REACH	PREAREA	POSTAREA	AREACHG	%
8.0	Jackass	NC	3006	3348	I	1.11
19.0	upper 19-mile	C	227	178	D	0.78
19.9	20 mile	C	329	431	I	1.31
20.4	upper North Canyon	C	399	405	S	1.02
21.5	22-mile Wash	C	138	399	I	2.89
21.9	22-mile	C	140	470	I	3.36
23.0	Indian Dick	C	714	1271	I	1.78
31.6	South Canyon	C	1397	1582	I	1.13
37.7	Tatahatso	C	433	581	I	1.34
39.0	Redbud Alcove	C	250	193	D	0.77
44.2	Eminence	NC	874	1231	I	1.41
47.3	Lower Saddle	NC	1571	2121	I	1.35
53.0	Main Nankoweap	NC	706	713	S	1.01
56.2	Kwagunt	NC	1224	1708	I	1.40
61.7	below LCR island	NC	985	195	D	0.20
64.7	Carbon	NC	300	881	I	2.94
66.8	Espejo	NC	155	194	I	1.25
74.3	lower Rattlesnake	NC	311	439	I	1.41
75.6	Nevills	NC	1988	4031	I	2.03
76.6	Hance	C	509	460	S	0.90
84.0	Clear Creek	C	45	289	I	6.42
84.4	above Zoroaster	C	314	832	I	2.65
91.1	lower 91-mile	C	324	384	I	1.19
94.3	94-mile	C	123	353	I	2.87
96.1	Schist	C	194	420	I	2.16
98.0	upper Crystal	C	341	253	D	0.74
103.8	Emerald	C	101	529	I	5.24
107.8	Ross Wheeler	C	299	98	D	0.33
109.4	110-mile	C	1451	421	D	0.29
114.3	upper Garnet	C	407	450	S	1.11
119.8	120-mile	NC	1532	1639	S	1.07
122.2	122-mile	NC	1864	1647	D	0.88
125.4	below Fossil	NC	605	812	I	1.34
131.1	below Bedrock	C	944	269	D	0.28
131.8	Galloway	C	203	199	S	0.98
132.0	Stone Creek	C	1012	1388	I	1.37
133.0	Talking Heads	C	243	472	I	1.94
134.6	Owl Eyes	C	1119	1838	I	1.64
136.0	Junebug	C	164	166	S	1.01
137.0	Backeddy	C	468	371	D	0.79
148.5	Lower Matkat	C	264	198	D	0.75
155.7	Last Chance	C	120	228	I	1.90
158.5	Second Chance	C	95	221	I	2.33
160.7	161-mile	C	227	653	I	2.88
166.6	lower National	NC	1264	1230	S	0.97
174.3	upper Cove	NC	582	868	I	1.49
174.4	lower Cove	NC	2080	2276	I	1.09
177.7	above Anvil	NC	315	421	I	1.34
188.2	lower Whitmore	NC	565	791	I	1.40
212.9	Pumpkin Springs	NC	354	778	I	2.20
219.8	upper 220-mile	NC	1336	1430	S	1.07
219.9	middle 220-mile	NC	1928	1294	D	0.67
222.0	222-mile	NC	489	615	I	1.26

APPENDIX C

List of new campsites (n = 82) in April 1996 two weeks after the flood.

These data are entered on a Lotus 1-2-3 spreadsheet file. Data columns are as follows:

MILE campsite location according to river mile
SIDE side of the river while facing downstream
CAPAC campsite capacity: number of people the site can accommodate
MAP list of sites that were mapped or measured; a blank cell indicates that neither was done:

MAP = the site was mapped
LXW = the site was measured by taking length by widths of campsite areas

PHOTO list of whether the site was photographed
POSTAREA campsite area in meters squared for campsites that were either mapped or measured in April 1996

MILE	SIDE	CAPAC	MAP	PHOTO	POSTAREA
8.5	L	30	MAP		578
12.2	L	18	MAP	Y	492
18.0	L	12	LXW	Y	362
28.3	L	10	MAP		53
30.2	R	25	MAP		435
32.4	L	33	LXW		421
35.1	L	11	MAP		42
35.2	R	12	LXW		184
37.8	R	11	MAP		360
38.1	L	15	LXW		361
39.2	R	12			
43.4	L	17			
44.3	L	25	LXW		1309
44.9	L	16	LXW		516
47.4	L	10			
47.5	L	15			
48.4	R	36	LXW		1020
48.5	L	17	LXW	Y	279
49.6	L	11			
50.1	R	22			
53.4	R	20	LXW	Y	720
53.8	L	20	MAP	Y	441
54.2	R	25	LXW	Y	506
54.9	R	18	MAP		226
55.4	L	18	MAP	Y	460
55.5	R	36			
56.4	R	25	MAP	Y	370
56.9	L	18			
57.0	R	18			
57.1	R	18			
57.2	L	25			
57.5	L	25			
58.3	L	15			
58.9	L	12			
59.9	L	25			
60.2	L	12			
60.9	R	36			
61.0	L	15			
62.0	R	26			
62.1	R	26			
62.7	R	28			
62.8	R	36			
64.2	R	28			
64.8	R	18	LXW	Y	1558
67.5	L	28			
68.5	L	11	LXW	Y	429
69.9	L	20			
75.1	L	11			
76.0	L	18			
76.1	L	20	MAP	Y	905
90.9	L	20	MAP		131
92.9	L	11		Y	
96.8	L	10			
97.6	R	12			
99.1	L	10			

MILE	SIDE	CAPAC	MAP	PHOTO	POSTAREA
99.6	L	18			
107.4	R	30	MAP	Y	213
115.5	L	26			
115.8	R	18	LXW	Y	275
117.5	R	25		Y	
122.5	L	18			
123.0	R	20			
123.4	L	18			
123.6	L	30			
125.2	R	18			
127.6	R	11			
153.5	R	15	MAP	Y	200
157.7	R	24	MAP	Y	352
172.9	R	16	MAP		405
184.0	R	20			
184.5	L	36	MAP	Y	1482
185.3	R	20			
196.0	R	24	MAP		584
198.2	R	20			
199.6	R	10			
200.5	R	30			
201.3	R	15			
204.3	R	10			
206.2	R	25	MAP		650
212.6	R	25			
219.1	R	17	MAP	Y	229
222.1	L	14			